(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 524 053 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
20.04.2005 Bulletin 2005/16

(51) Int Cl.[7]: **B23B 29/04**, B23B 29/24

(21) Application number: **04445104.5**

(22) Date of filing: **04.10.2004**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LI LU MC NL PL PT RO SE SI SK TR
Designated Extension States:
AL HR LT LV MK

(30) Priority: **16.10.2003 SE 0302729**

(71) Applicant: **SANDVIK AKTIEBOLAG**
811 81 Sandviken (SE)

(72) Inventor: **Englund, Kjell**
818 00 Valbo (SE)

(74) Representative: **Taquist, Lennart et al**
Sandvik AB,
Intellectual Property
811 81 Sandviken (SE)

(54) A cutting tool, a part thereof, as well as a method for the manufacture of such a cutting tool

(57) In a first aspect, the invention relates to a cutting tool of the type that comprises two parts (1, 2), which are releasably interconnectable via serration surfaces (3, 4), which are mechanically engageable in each other. Characteristic of the invention is that at least one of the parts (1) is composed of a first body (21), as well as a second, supplement-like body (22) on which the serration surface (3) of the part (1) is formed, and which via a permanent joint is stiffly united to the first body (21). In a second aspect, the invention also relates to an individual tool part as such. In a third aspect, the invention also relates to a method for the manufacture of cutting tools of the kind in question.

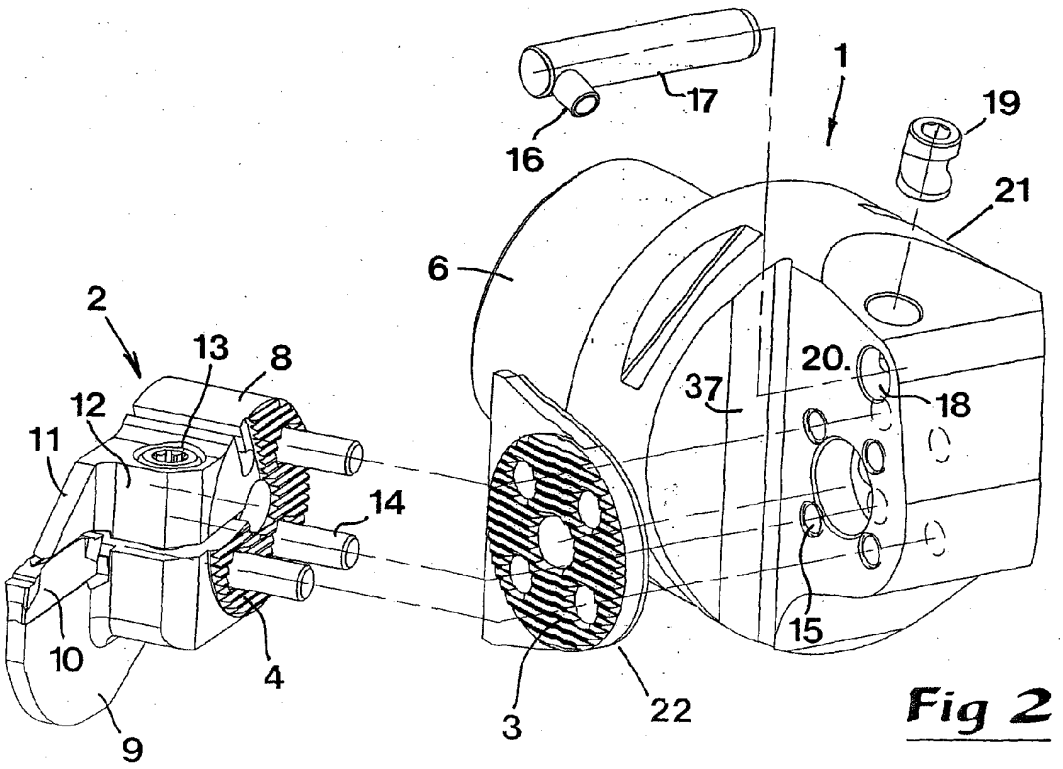

Fig 2

EP 1 524 053 A2

Description

Technical Field of the Invention

[0001] In an aspect, this invention relates to a cutting tool of the type that comprises two parts, which are releasably interconnectable via serration surfaces, which are mechanically engageable in each other.

Prior Art

[0002] An overwhelming share of the tools, which are found in all three main disciplines within the modern technique for cutting or chip-removing machining, are assembled from two or more parts, which can be released from each other. For instance, cutting inserts and other types of hard machining members are mounted on miscellaneous basic bodies or coupling parts, when rotatable tools, such as milling cutters and drills, are concerned. In turning tools, a coupling part or adapter is most often included with which an insert-carrying or edge-carrying machining part is releasably connected, e.g. a blade part having a slotting tool for parting or groove-slotting operations. A general requirement on all kinds of cutting tools, which are composed of two or more parts, is that repeated mounting and dismounting of the parts should be able to be carried out while retaining good precision between the parts in question, e. g. between a basic body and a cutting insert clamped in a tool holder, so far that the position in space for one or more chip-removing cutting edges always should be one and the same, regardless if one of the parts frequently is dismounted and exchanged, respectively. The requirements on such position precision are also high in respect of rigidity and shape stability in the joint between the parts. Thus, the joint should withstand prescribed force loads without the cutting edges being dislodged from the predetermined, geometrically exact positions thereof.

[0003] Against the background above, it has recently become more and more popular to realize the joint between releasably connected tool parts by means of so-called serration surfaces on the respective parts. The concept of serration surface (at times only "serration") as this is used by those skilled in the art is extensive and partly vague, so far that it encompasses a number of different practical embodiments. However, in the simplest form thereof, a serration surface includes a plurality of straight and mutually parallel ridges, which are spaced apart by intermediate scores or flutes, and which are intended to engage scores present between analogous ridges in the second serration surface with which the same should cooperate. The ridges in older serration surfaces have a genuine trapezoid cross-section shape, so far that the individual ridge profile is formed with entirely planar or smooth flanks, which form approximately an angle of 60° to each other. However, recently serration surfaces have also been developed, the ridges of which have a partially curved shape with the purpose of improving the contact between the flanks (see the SE-patent 0100052-0). Furthermore, characteristic of serration surfaces or connecting surfaces of the kind in question is that the tops or crowns of the ridges do not bottom in the appurtenant scores. In such a way, it is guaranteed that only the flanks of the ridges are pressed against each other, the ridges being steadily wedged up in each other. Serration surfaces that solely make use of straight and mutually parallel ridges are single-acting in the sense that they (in addition to rotation) prevent straight relative motions between the respective parts in only one direction, viz. in a direction perpendicular to the length extension of the ridges. However, straight relative motions are not prevented in the direction parallel to the ridges. Therefore, the purpose of preventing relative motions of the last-mentioned type has to be solved in another way, e.g. by fixation by means of different types of clamping elements, such as screws, clamps, etc., or by cooperation between holder-ons and shoulders on the respective parts. To the category single-acting serration surfaces, such elementary embodiments, which include only one straight ridge in one of the tool parts and a complementary score in the second part, are frequently also counted.

[0004] In addition to single-acting serration surfaces, serration surfaces are also found that are double-acting, so far that they prevent relative motions in two directions perpendicular to each other between two coupled parts. One type of such surfaces consists of so-called cross serrations, which make use of one or more ridges/scores extending at an angle, e.g. a right angle, to one or more other ridges/scores in the same surface. A particular sub-group of such surfaces are formed with honeycomb patterns made by a plurality of parallel scores in a first set of scores and ridges being brought to intersect the ridges in a second set of ridges and scores, which extend at a right or an other angle to the scores/the ridges in the first set.

[0005] In SE 0200867-0 a recently developed type of serration surfaces is furthermore described in which the ridges and scores generally have a curved shape instead of a straight one. These also belong to the category double-acting serration surfaces because they prevent translation motions in two directions perpendicular to each other.

[0006] When a serration surface is found on, for instance, a compression-moulded (and sintered) cemented carbide insert, the design of the same does normally not offer any difficulties of any note. However, when a corresponding serration surface should be formed on another, co-operating part, such as a basic body, a coupling part, an adapter, at times problems difficult to master may arise. Such parts are primarily made from steel, the serration surface being formed by suitable machining in the steel material, such as milling, grinding, hobbing, sparking, etc. By virtue of the physical shape of the individual tool part, which at times may be fairly com-

plicated, it may, however, become difficult and at times impossible to form a serration surface having the desired shape on the very surface field on which serrations are desirable. An example of a tool that is difficult to form with serration surfaces consists of the slotting tool, which is shown on the appended drawings with the purpose of illustrating the invention. However, in addition to turning tools, numerous examples of rotatable tools are also found, such as drills and milling cutters, in which the surface fields in question are difficult to access for, for instance, a milling cutter with the purpose of mill cutting a serration surface. In this connection, it should also be pointed out that a surface field in question on a basic body or the like, may be accessible, per se, for achievement of a single-acting serration surface, i.e., a surface which includes ridges, which all extend in one and the same direction, but where double-acting serration surfaces are impossible to provide because the milling cutter can only be moved in one direction. Many times, also mediocre compromises are resorted to, which, for instance, consist of locating the serration surface farther away from an obstacle to the milling cutter than what is desirable; something that in turn may lead to the cutting tool becoming longer or more ungainly than necessary.

Objects and Features of the Invention

[0007] The present invention aims at managing the above-mentioned problems and at improving the flexibility in respect of the possibilities of forming cutting tools having expedient serration surfaces independently of the type, shape or location thereof on the tool. Thus, a primary object of the invention is to provide a cutting tool, which can be formed of parts, which do not require milling or the like machining with the purpose of integrating a desired serration surface in the same. An additional object is to provide a cutting tool having a serration surface formed on at least one part of the tool, which if required may be given other properties, e.g. in respect of hardness, strength and resistance to wear, than those properties that are determined by the material in the proper tool part.

[0008] According to the invention, at least the primary object is attained by the features defined in the characterizing clause of claim 1. Preferred embodiments of the cutting tool according to the invention are further defined in the dependent claims 2-9.

[0009] In another aspect, the invention also relates to a part belonging to a cutting tool of the type that comprises a serration surface for mechanical engagement with an analogous serration surface on another tool part. The features of this tool part are seen in claim 10.

[0010] In an additional aspect, the invention also aims at providing a method for the manufacture of cutting tools of the kind in question. The features of this method are seen in the independent claim 11.

Summary of the Invention

[0011] The invention is based on the intention to assemble the part or the parts of a cutting tool, which should carry a serration surface, from a first body as well as a second, supplement-like body, on which the serration surface is formed, and which via a permanent joint is stiffly united to the first body. The supplement-like body, which carries the serration surface, may for instance be in the form of a comparatively thin plate, one side of which is entirely or partly occupied by a serration surface, and the opposite side of which is permanently connected to the first body or main body, which forms a main component in the tool part in question and which usually is manufactured from steel. The permanent joint between the two bodies in the tool part can be realized in many different ways and may also include a plurality of different types of part joints. In order to, from a general point of view, retain the serration surface-carrying body on the main body, welded joints or glue joints may accordingly be utilized. However, simultaneously the permanent joint may also include means in order to prevent or counteract rotary as well as translation motions between the bodies (besides the welded joint or glue joint).

[0012] In this connection, it should be pointed out that, in cutting tools, it is previously known to use plate-shaped shims having a serration surface on at least one of the two opposite sides (at times on both sides). Such shims are particularly usual between cutting inserts and basic bodies. However, in such cases, the shim is not permanently united to the appurtenant basic body, but may be released in the same way as the cutting insert.

Brief Description of the Appended Drawings

[0013] In the drawings:

- Fig. 1 is a perspective view of a cutting tool that has been exemplified in the form of a turning tool, which is intended for parting or groove slotting and which includes two parts releasably coupled together with each other, viz. an adapter and a blade part, in which a slotting tool is applied,
- Fig. 2 is a perspective exploded view showing the blade part separated from the adapter, as well as a plate formed with a serration surface separated from the real adapter body,
- Fig. 3 is a perspective exploded view showing the adapter body, the serration plate and a shim therebetween,
- Fig. 4 is a perspective exploded view showing the back sides of the serration plate and of the shim,
- Fig. 5 is a planar view illustrating an alternative embodiment of a serration plate, and
- Fig. 6 is a perspective exploded view showing the invention applied on a multifunctional cutting

tool.

Detailed Description of Preferred Embodiments of the Invention

[0014] The cutting tool illustrated in figs. 1 and 2 includes two parts 1, 2, which are releasably connected or possible to couple together with each other via serration surfaces 3, 4. When said surfaces 3, 4 are brought to engagement with each other, the same are included in an interface designated 5 (see fig. 1) between the parts 1 and 2. In the chosen embodiment example, the tool consists of a turning tool, more precisely a so-called slotting tool of the type that is used for parting or groove-slotting operations. Therefore, the part 1 consists of an adapter or coupling part, which includes a rear coupling piece 6 and a front, coarser head 7.

[0015] The part 2 consists in turn of a machining part, which commonly is denominated blade part, and which in addition to a comparatively robust body 8 includes a leaf-shaped portion 9, in which a thin, replaceable slotting tool or cutting insert 10 may be clamped. In the usage state of the tool, the serration surface 3 is integrated with the adapter 1, while the serration surface 4 is included in the releasable, insert-carrying machining part 2. In this connection, reference being made to fig. 2, it should be pointed out that the cutting insert 10 is clamped in the appurtenant seating by means of a nose 11, which is included in an upper, elastically resilient portion 12 in the body 8, and which can be clamped against the lower portion of the body by means of a tightening screw 13. Furthermore, the part 2 includes three laterally projecting screws 14, which are tightenable in threaded holes 15 in the adapter 1, and which have the purpose of fixing the parts 1 and 2 in relation to each other.

[0016] In the usual way, also a nozzle or outlet 16 is included in the tool for spraying of cooling liquid or the like against the cutting insert 10. Such cooling liquid is fed forward through channels in the interior of the adapter 1, more precisely from the tool holder (not shown) in which the coupling piece 6 is fixed. In the example, the nozzle 16 is included in a transverse sleeve 17, which is releasably mounted in a bore 18 by means of a clamping device 19.

[0017] As far as the shown tool has been described hitherto, the same is in all essentials previously known.

[0018] In previously known tools, the serration surface 3 has been formed directly in the body usually consisting of steel and that forms the adapter 1, more precisely in the side surface that in figs. 1 and 2 is designated 20. When this design has been effected by milling, it has been necessary to locate the surface sufficiently far from the transverse wall, which projects from the rear limitation of the surface 20, for the milling cutter to go free from the wall.

[0019] Characteristic of the present invention is that the tool part 1 is composed of a first body 21, as well as a second, supplement-like body 22 on which the serration surface 3 is formed, and said two bodies being permanently united to each other via a joint, which can be realized in various ways, but which henceforth is denominated permanent joint. Concerning the bodies 21, 22, it may generally be said that the first body 21 forms a main body, which in practice is generally greater than the second body or supplement body 22.

[0020] Now reference is also made to figs. 3 and 4, which more in detail illustrate the nature of the serration-carrying supplement body 22. In the shown, preferred embodiment, the body in question has the shape of a plate, the thickness of which may vary. However, the thickness of the plate 22 should in all events be smaller than the smallest extension of the serration surface 3 in question. Expressed in absolute numbers, the thickness of the plate should be within the range of 1-6 mm, suitably 2-4 mm. The two opposite sides or major faces 23, 24 of the plate are advantageously - although not necessarily - planar and mutually parallel. In the example, the serration surface 3 is of a single-acting type, i.e., the same includes a plurality of straight and mutually parallel ridges between which scores are defined having an analogous shape. The surface field that is occupied by the serrations has in this case a circular shape, while the contour shape of the plate in its entirety is different. More precisely, the plate has a partially circular and partially triangular shape, so far that the same is delimited by a part-cylindrical edge surface 25, which transforms into two plane and straight edge surfaces 26, which extend at an acute angle to each other, and which end in a common, rear edge surface 27, which is straight and forms the base in an imaginary triangle.

[0021] As has been mentioned above, the permanent joint between the plate 22 and the main body 21 may be realised in various ways. One feasible way is to agglutinate the back side 24 of the plate against the planar side surface 20 of the main body. However, in the embodiment shown, a welded joint between the components in question is preferred. More precisely, welding may be effected by means of a laser welding technique, which recently has been developed and which in detail is described in the applicant's simultaneous patent application with the denomination "CUTTING TOOL TOGETHER WITH A METHOD FOR THE MANUFACTURE THEREOF". Briefly, this technique is based on the intention of applying a shim in a gap between two tool parts, which should be welded together, which shim in a cool state is welded along the periphery thereof by means of at least one laser beam, which at a significant speed is brought to be moved along the periphery of the shim. During the movement thereof in relation to the shim and surrounding portions of the tool parts, the laser beam melts the metal in the shim and the tool parts, respectively, in very limited, almost point-like areas, the size of which is determined by the diameter of the laser beam. In such a way, welding and the ensuing heat release take place very locally in a point area, which quick-

ly is moved along the shim. This ensures that heat deformations, heat embrittlement and the like, do not arise in the interfaces or contact surfaces between the shim and the tool parts.

[0022] In figs. 3 and 4, such a welded shim 28 is shown, which generally is ring-shaped and has a contour shape that substantially corresponds to the contour shape of the plate 22. Furthermore, the shim is thin and flat, so far that it is delimited by two planar surfaces 29, 30, intended to be pressed against the surfaces 24 and 20, respectively. The thickness of the shim may in practice be within the range of 0,5-1,0 mm. A hole designated 31 in the shim has substantially the same diameter as a cylindrical shoulder 32 on the inside of the plate 22. A planar surface 33 on said shoulder is pressed against the surface 20. The shoulder has substantially the same thickness as the shim 28, from which it follows that the shim substantially completely fills out the ring-shaped gap, which is formed between the surfaces 20, 24 upon assembly of the bodies 21, 22.

[0023] In practice the main body 21 of the exemplified adapter may be manufactured from carbon steel, e.g. a steel of the type THG 2000, which is a chrome-molybdenum-vanadium-alloyed steel, the carbon content of which is within the range of 0,35-0,42%. Also in the supplement body or plate 22, a steel may be used having a certain carbon content, e.g. 332541 or 332230. In such cases, the shim 28 may advantageously be made from an austenitic steel, in particular an austenitic steel of a stainless type, i.e., a material that has been alloyed with suitable quantities of chromium and nickel.

[0024] In this connection, it should be pointed out that the invention, by the measure of forming the serration surface in a separate supplement body, offers the advantage of forming the supplement body from a material having entirely other properties than the material in the main body 21. In particular, the possibility is offered of making the supplement body from a material that is considerably harder and more resistant to impact, heat and wear than the material in the main body. A particular advantage in this respect is that the supplement body can be manufactured in another way than the main body, e. g. by compression moulding instead of by steel machining.

[0025] From the centre of the shoulder 32, a male member 34 extends in the form of a spigot, which is intended to co-operate with a female-like seating 35 in the main body 21. Said male spigot 34 has a cylindrical or rotationally symmetrical envelope surface 36, the diameter of which is somewhat (0,01-0,03 mm) greater than the inner diameter of the cylindrical surface that defines the seating 35. When the spigot is inserted into the seating, accordingly a press fit is established between the contact surfaces.

[0026] Although the described welded joint (or alternatively a glue joint) by itself counteracts displacements or relative motions between the bodies 21, 22, the male-female joint formed by the spigot 34 and the seating 35 also contributes to a large extent to fix the bodies in relation to each other. Regardless if the forces that act on the plate 22 are oriented parallel or perpendicularly to the ridges and the scores in the serration surface 3, hence the male-female joint guarantees a stable anchorage of the plate in relation to the main body 22. However, the male-female joint does not contribute to preventing rotation of the plate around the geometrical centre axis C, which is constituted by the spigot and the seating. Here also it applies that the weld or glue joint counteracts tendencies of the plate to be angularly displaced, but in order to additionally strengthen the joint in respect of torsion stresses, the invention envisages a particular, additional part joint of mechanical character. Thus, the main body 21 is formed with a shoulder surface 37, which extends at an angle, suitably right angle to the surface 20, and has the purpose of co-operating with the straight, rear edge surface 27 on the plate 22. If the angle between the surfaces 20 and 37 is right, the planar rear edge surface 27 of the plate 22 extends perpendicularly to the plane of the plate. In addition, the radius or the radial distance between the edge surface 27 and the geometrical centre axis C of the spigot 34 is at least equally large as the distance between the same geometrical centre axis C of the seating 35 and the transverse surface 37. If the first-mentioned distance is some or a few hundredths of a millimetre greater than the last-mentioned one, the surfaces 27, 37 are pressed against each other with a certain press fit, when the spigot 34 is pressed into the seating 35. In such a way, a distinct mechanical locking of the plate in relation to the main body 21 is provided; something which in practice eliminates the risk of rotating the plate in relation to the main body.

[0027] In fig. 5, an alternative and in practice preferred embodiment of the serration-carrying supplement body 22 is shown. In this case, the rear edge of the supplement body is formed with two projections 38 spaced-apart in the longitudinal direction having planar support surfaces 27' for abutment against the shoulder surface 37 on the main body 21. By reducing the area of the support surfaces 27' and distance the same from each other in this way, a two-point support is provided, which improves the conditions for a firm pressing of the supplement body against the shoulder surface 37. A two-point support may also be provided by means of a central countersink in the shoulder surface 37, at the same time as a straight rear edge surface 27 is kept on the supplement body 22.

[0028] In fig. 6 an example of another cutting tool is shown, to which the invention is applicable. This tool consists of a recently developed so-called multitool having a coupling part 1' clampable in a tool holder, which coupling part includes a head 39 on which a plurality of machining parts 2' are applicable and possible to fix by means of co-operating pairs of serration surfaces 3, 4. In accordance with the invention, said serration surfaces are formed on separate addition bodies or plates that

are countersunk in the appurtenant tool part, above all in the head 39 of the coupling part.

[0029] The possibility of countersinking the addition plate or body formed with a serration surface in the main body of the tool part offers, by itself, an interesting possibility of providing rotation lock of the plate. Namely, if the plate and the countersink in which the same is housed are given an out of round shape, e.g. polygonal, each form of rotary motions between the plate and the main body is made impossible in an easy, mechanical way.

Feasible Modifications of the Invention

[0030] The invention is not limited only to the embodiments described above and shown in the drawings. Thus, the invention is in no way limited to the type of turning tool and multitool, respectively, that are shown in figs. 1 and 6, but may be applied to any other cutting tools, such as other turning tools and rotatable tools, respectively, in the form of milling and drilling tools. In this connection, the physical shape of the main body and the serration-carrying supplement body that together form an integrated unit is of no principal importance. Although a welded joint provided by means of laser technique is preferred in the requisite permanent joint between the two part bodies of the tool part in question, other joints, such as glue joints, may also be used. Furthermore, the mechanical locking means that advantageously - though not necessarily - may be included in the permanent joint, and that have the purpose of counteracting rotary and translation motions, respectively, between the bodies, may be realized in another way than the one exemplified. In particular, the means of avoiding rotation may be varied in multiple ways within the scope of the general idea according to the invention. This is also valid in respect of the design of the serration surfaces in question. Instead of single-acting serration surfaces having only one type of straight serrations (= ridges and scores), the surfaces or the coupling means in question may have arbitrary shape. The only essential is that the two co-operating surfaces include male and female-like members that may engage each other mechanically with the purpose of counteracting relative motions between two coupled tool parts. In other words, application of the invention may be postulated also in connection with serration surfaces that may be developed in the future.

List of Reference Designations

[0031]

1 = tool part
2 = tool part
3 = serration surface
4 = serration surface
5 = interface
6 = coupling piece
7 = head
8 = body
9 = blade portion
10 = cutting insert
11 = nose
12 = spring portion
13 = tightening screw
14 = spigots
15 = hole
16 = nozzle
17= sleeve
18 = bore
19 = clamping device
20 = side surface
21 = part body
22 = supplement body
23 = plate side
24 = plate side
25 = cylindrical edge surface
26 = straight edge surface
27 = end edge surface
28 = shim
29 = plane surface
30 = plane surface
31= hole
32 = shoulder
33 = plane surface
34 = male spigot
35 = seating
36 = envelope surface
37 = shoulder surface
38 = support projection
39 = head

Claims

1. Cutting tool comprising two parts (1, 2), which are releasably interconnectable via serration surfaces (3, 4), which are mechanically engageable in each other, **characterized in that** at least one of the parts (1) is composed of a first body (21), as well as a second, supplement-like body (22) on which the serration surface (3) of the part (1) is formed, and which via a permanent joint is stiffly united to the first body (21).

2. Cutting tool according to claim 1, **character-ized in that** the supplement body consists of a plate (22), the thickness of which in any case is smaller than the smallest extension of the serration surface (3).

3. Cutting tool according to claim 1 or 2, **characterized in that** the permanent joint comprises a welded joint in an interface (5) between the first and second bodies (21, 22).

4. Cutting tool according to claim 3, **character-ized in that** in said interface (5) a peripherically opening gap is formed in at least one of the two bodies, in which gap a separate, metallic shim (28) is applied, which has a shape that is predetermined and corresponding to the shape of the gap, and which along the outwardly exposed periphery thereof is laser welded against the two bodies while forming said welded joint.

5. Cutting tool according to claim 4, **character-ized in that** at least one of said bodies (21, 22) is manufactured from carbon steel, and that the shim (28) consists of an austenitic steel.

6. Cutting tool according to claim 4 or 5, **characterized in that** the shim has the shape of an endless, flat ring (28), which is welded against two ring-shaped contact surfaces (23, 24) facing each other, on the two bodies (21, 22).

7. Cutting tool according to any one of the preceding claims, **characterized in that** the permanent joint includes a male-female joint formed of a male member (34) included in the supplement body (22), which male member is inserted with press fit in a female-like seating (35) in said first body (21) and has the purpose of counteracting straight relative motions between the bodies.

8. Cutting tool according to any one of the preceding claims, **characterized in that** the permanent joint includes means (27, 37) of counteracting rotation of the supplement body (22) in relation to said first body (21).

9. Cutting tool according to claim 8, **characterized in that** said means consists of an edge (27), being present on the supplement body (22) and having an out of round basic shape, arranged to be pressed against a shoulder (37) being included in the first body (21) and having an analogous or complementary shape.

10. Part (1) belonging to cutting tool of the type that comprises a serration surface (3) for mechanical engagement with an analogous serration surface on another tool part, **characterized in that** the same is composed of a first body (21), as well as a second, supplement-like body (22) on which the serration surface (3) is formed, and which via a permanent joint is stiffly united to the first body (21).

11. Method for the manufacture of cutting tools of the type that comprises two parts (1, 2), which are releasably interconnectable via serration surfaces (3, 4) mechanically engageable in each other, **characterized in that** at least one of the parts (1) is assembled from a first body (21), as well as a second, supplement-like body (22) on which the serration surface (3) of the part is formed, and which via a permanent joint is stiffly united to the first body (21).

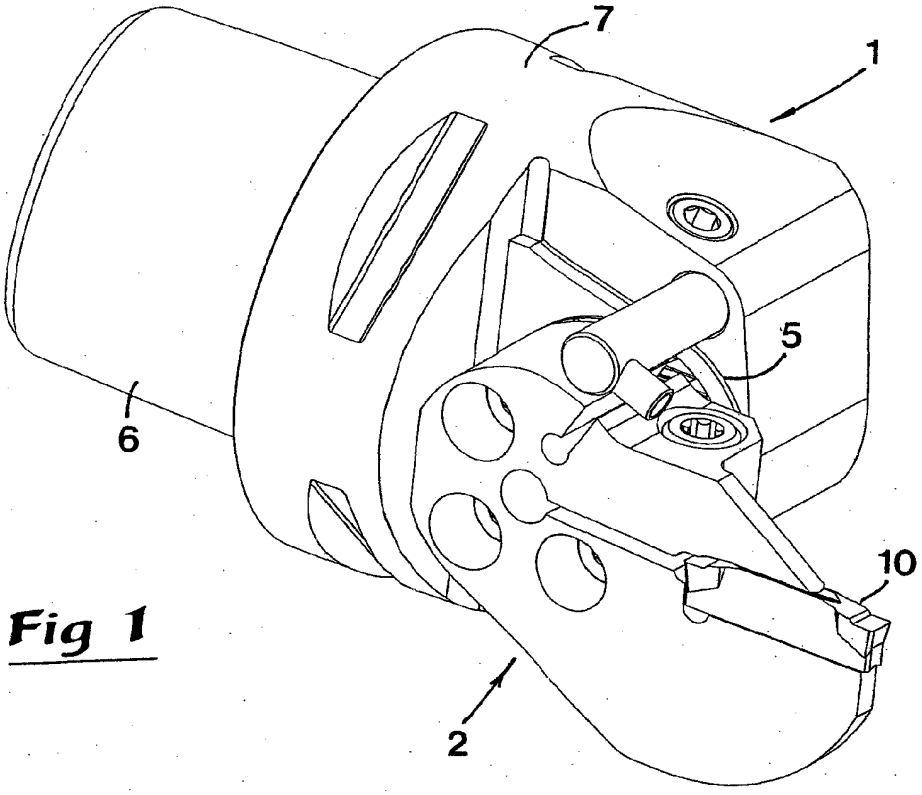

Fig 1

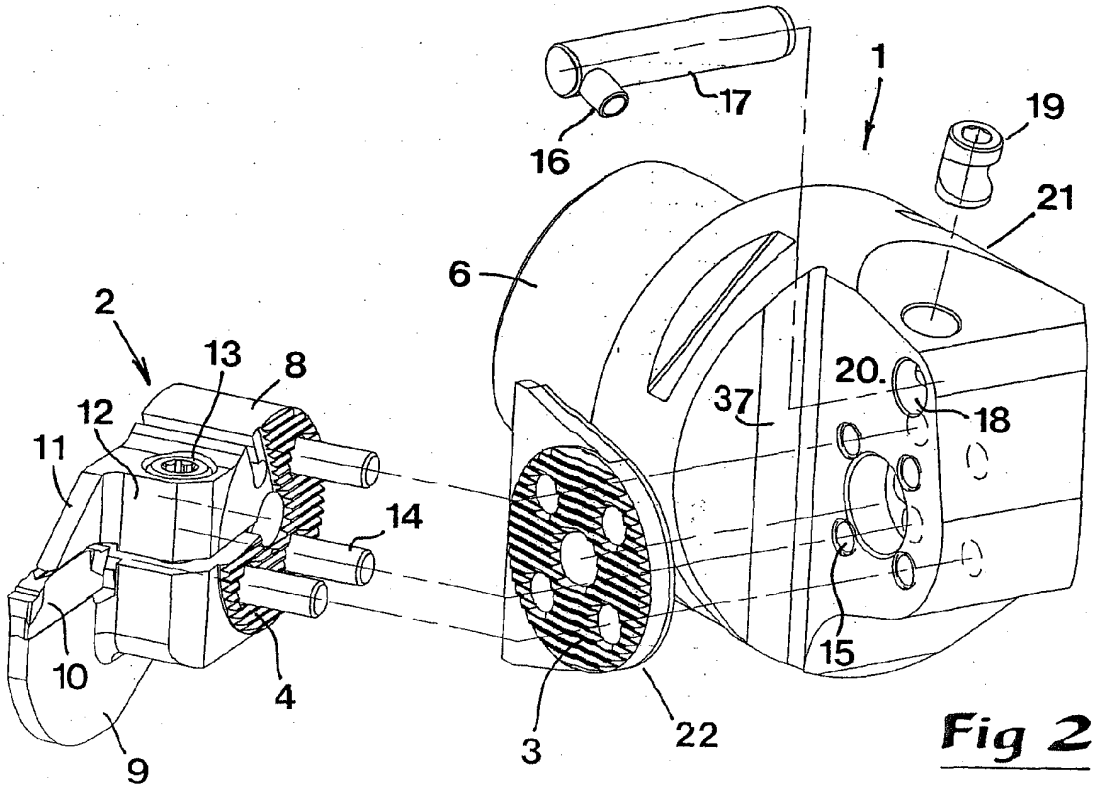

Fig 2

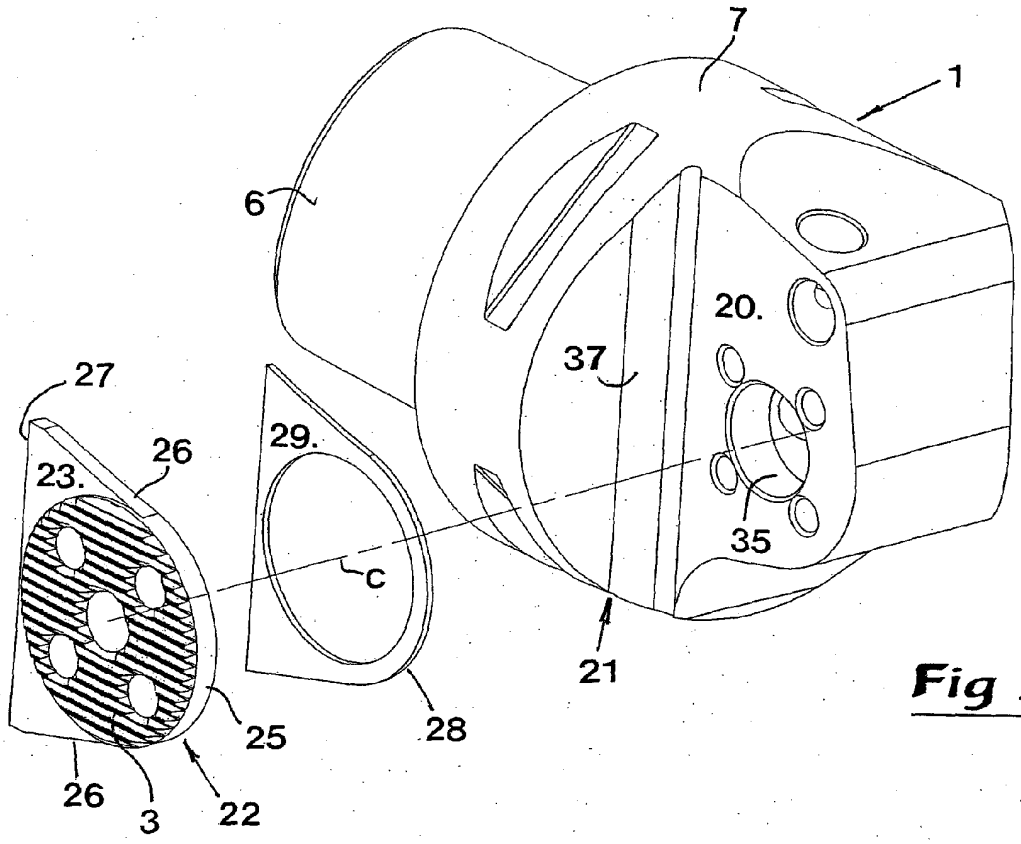

Fig 3

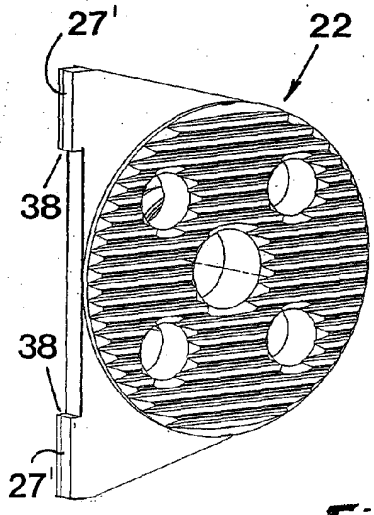

Fig 5

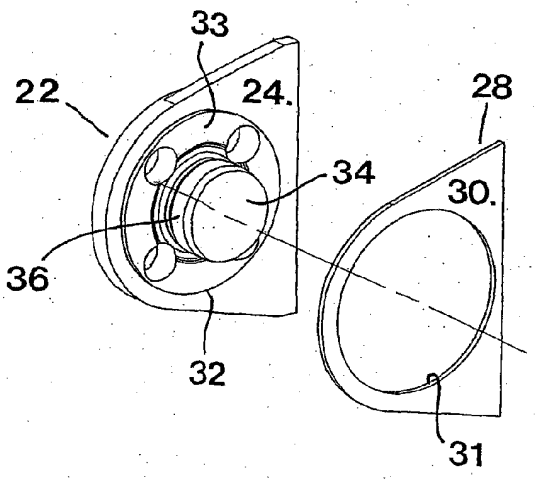

Fig 4

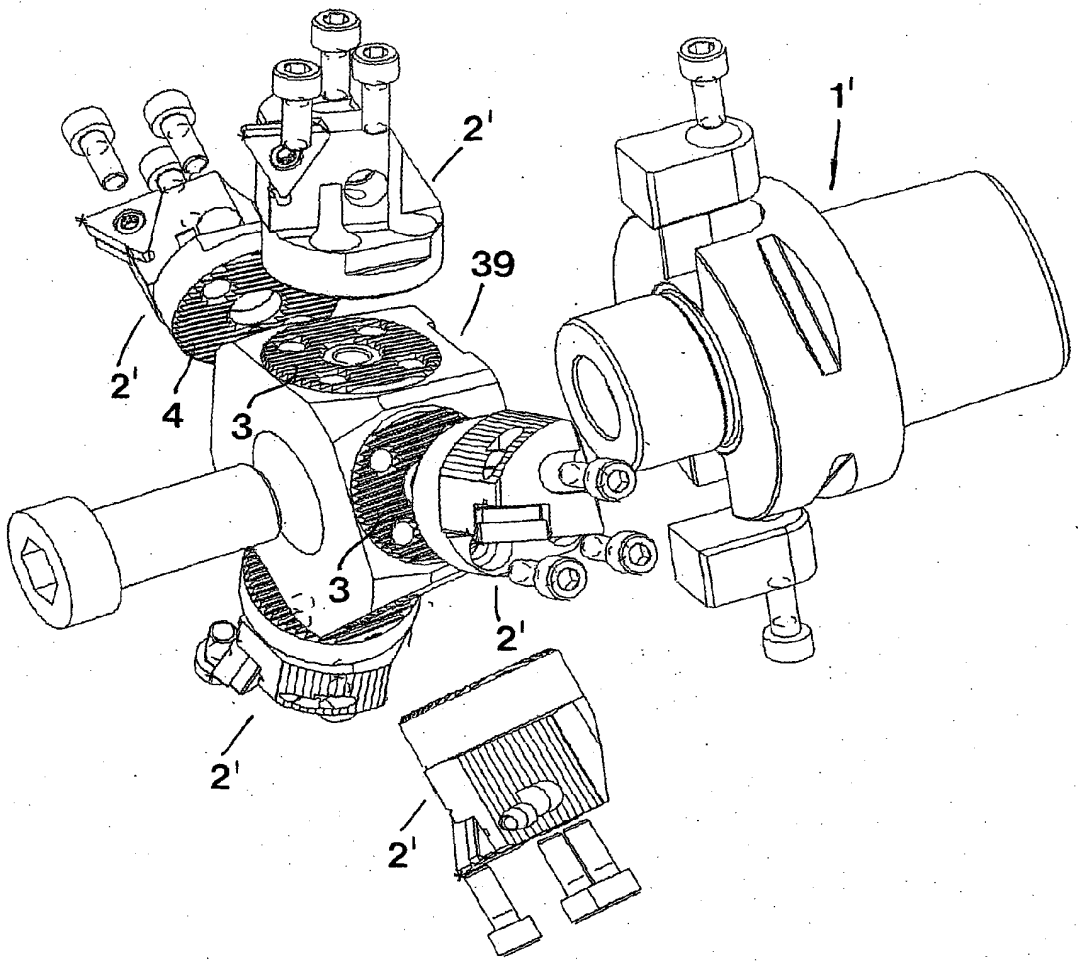

Fig 6